Express Mail No. EL 915035133 US

ANDREW DOCKET: 574-577
WHE DOCKET: ANCO-06

APPLICATION

FOR

UNITED STATES LETTERS PATENT

TITLE: SHARED TOWER SYSTEM FOR ACCOMMODATING MULTIPLE SERVICE PROVIDERS

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SPECIFICATION

SHARED TOWER SYSTEM FOR ACCOMODATING MULTIPLE SERVICE PROVIDERS

Field of the Invention

This invention relates generally to the provision of cellular services and specifically to the accommodation of multiple service providers from a single cellular tower.

Background of the Invention

In the provision of wireless communication services within a cellular network, individual geographic areas or "cells" are serviced by one or more base stations. A base station has at least one cellular tower associated therewith, utilizing RF antennas which communicate with a plurality of remote devices, such as cellular phones and paging devices. The tower is then linked with other facilities of the service provider, including a switching office, for handling and processing the wireless communication traffic. The tower might be coupled to the switching office through land lines, or alternatively, the signals might be transmitted or backhauled through microwave backhaul antennas. Another tower might also be involved for delivering the wireless traffic to the switching office or another site. Generally, a tower will have various RF antennas and microwave

backhaul antennas associated with each of the different wireless service providers, such as AT&T, Sprint, Verizon, and others having coverage for the area where the tower is located. As may be appreciated, each cellular tower generally accommodates a plurality of RF and/or microwave backhaul antennas.

Traditionally, cellular base stations and towers were owned and operated by the service providers. However, today, such towers are owned by third-party companies who are driven to operate the towers as efficiently and profitably as possible. To that end, and to maximize profits, cellular towers often accommodate multiple service providers desiring coverage in a geographic area. However, there are physical capacity limits for cellular towers which limit the capacity of the towers in handling all of the equipment for all possible service providers. Specifically, a greater number of service providers for a cell or cell sector has translated into additional equipment being loaded onto the tower. However, the physical tower loading must remain within desired parameters for the integrity of the tower.

For example, on a typical cellular tower, multiple providers (Q) each might have sets of 6-9 RF link antennas on a single tower. Such antennas, in addition to their own weight, each require Q x (6-9) cables. In addition to the RF link antennas, there will often be multiple microwave backhaul antennas (P), directed at various orientations around a 360° axis, adding not only additional antenna weight, but also requiring P additional cables or waveguides hanging from the tower. Adding additional service providers and the hardware associated therewith, will therefore, tax the

tower to its physical capacity. Furthermore, weight is not the only concern, as the antennas and cables increase wind resistance for towers that must withstand 60 mile/hour winds. Still further, ice on the various antenna hardware and cables will further increase physical strain on a tower. Therefore, the physical capacity of the tower currently limits the ability to serve every interested service provider, and therefore limits the revenue of the tower owners in selling their tower space to service providers.

Simply building more towers is not a desirable solution. In addition to the cost to build and maintain the tower, communities are starting to vigorously protest the location of such towers due to their unsightly addition to the landscape. This is particularly so in densely populated areas where more towers might be needed or coverage is particularly desired by the service provider.

Another revenue limiting issue for tower owners is that there is only one tower top. The most desirable position for a service provider is to be operating from RF link or microwave backhaul antennas positioned at or very close to the top of the tower. The highest amount of revenue, or tower rent fees, for a tower operator is generated by those service providers using equipment at the top of the tower. Those service providers with equipment located below the tower top, understandably, will only pay lesser fees.

Another particular concern for service providers is the shape and direction of their signal beams. Different providers have different demands, thus putting a further burden on tower owners. While tower owners may provide specific beams to a service provider, such an option

is often expensive, and will usually require additional equipment on the tower for that specific service provider. Furthermore, offering the service to one tower customer creates a desire by other tower customers, requiring even more equipment and expense to maintain the customers.

Consequently, tower operators have various factors to consider as they sell their tower services to wireless service providers. Traditionally, the tower operators have worked to sell their tower space and to put as much equipment on a tower as they could physically accommodate. The tower owners would like to have every possible service provider on their towers. Of course, every service provider will want the tower top location and will want special considerations, such as specific beam shapes or directions. As such, there exists a tension in the tower market due to limitations in the current technology which limits not only the revenues of the tower owner but also the benefits to be received by a service provider.

Therefore, it is desirable for a tower operator to increase revenues by accommodating every potential service provider customer on the tower.

It is further desirable, both from a revenue standpoint for the tower owner and a performance standpoint for the service provider, to have all service providers located at the tower top.

In addition to accommodating all of the service providers, the tower owner also wants to be able to meet the specific performance criteria of each of their potential service provider customers, including beam considerations, in order to entice them to purchase the services of the tower owner.

Brief Description of Drawings

The accompanying drawings, which are incorporated in and constitute a part of this specification, illustrate embodiments of the invention and, together with the detailed description of the embodiments given below, serve to explain the principles of the invention.

Figure 1 is a perspective view of the traditional cellular tower.

Figure 2 is a perspective view of a cellular tower incorporating an embodiment of the present invention.

Figure 3 is a circuit block diagram of one embodiment of the present invention.

Figure 3A is a schematic diagram of an antenna structure of one embodiment of the invention.

Figure 3B is a block diagram of signal processing circuitry for an embodiment of the invention.

Figure 4 is a circuit block diagram of an alternative embodiment of the present invention.

Figure 5 is a circuit block diagram of an alternative embodiment of the present invention.

Detailed Description of Embodiments of the Invention

The invention addresses the above-noted desires and needs in the art and provides a system for accommodating multiple service providers on a single tower. While the invention described herein is described in connection with various preferred embodiments, it is understood that the invention is not limited to those particular embodiments. Rather, the description of the invention is intended to cover various alternatives, modifications, and equivalent arrangements as may be included within the scope of the invention as defined by the application.

The present invention relates to the concept of sharing a cellular tower among multiple service providers, while providing those service providers with tower top locations for their equipment, as well as tailored beams for their signals. Such a concept is applicable to the RF link systems on a tower, as well as the microwave backhaul systems on the same tower. The system allows for maximizing revenue for a tower owner while providing desirable performance characteristics for a wireless service provider.

Figure 1 shows a schematic view of a typical base station cellular tower 10 having RF link and microwave backhaul equipment of multiple service providers thereon for facilitating wireless communication, according to aspects of the present wireless technology. Tower 10 will generally be owned by a tower operator who desires to sell or rent use of the tower to wireless service providers, such as AT&T, Sprint, and Verizon, to name just a few possible service providers.

Tower 10 includes one or more sets of RF link antennas, 12a, 12b, and 12c (corresponding to the multiple service providers on the tower) for providing the wireless communication link between the base station of tower 10 and a plurality of remote devices, such as cellular phones, pagers, and other wireless devices. Also associated with the tower are one or more backhaul antennas, or sets of antennas, indicated by reference numerals 14a, 14b, and 14c, which provide microwave backhaul of the communication signals, such as to a switching office for a service provider, or to another tower. The tower will usually include one or more land lines (not shown) such as for communication with the switching office or a remote location. Also associated with tower 10, but not shown in the drawings, are base station electronics, usually located at the base of the tower, which encompass any of the electronics not included at the antennas or up on the tower for processing wireless communications. Cables running from the various RF link antennas 12a-12c and microwave backhaul antennas 14a-14c run down to the electronics at the base of the tower and, as noted above, add to the weight and complexity of the tower equipment. Any additional equipment added to tower 10 diminishes the future capacity of the tower.

An RF link system 12a will include sets of RF antennas 16 with each set facing a portion or sector of a cell associated with tower 10. In Figure 1, a tower defining three sectors is illustrated, although other numbers of sectors might also be defined by the tower. Generally, Figure 1 shows three RF antenna structures 16 facing each of three defined sectors. Furthermore, based upon the orientation of the RF link

system12a-12c on the tower, each RF link system is generally shown to be oriented to service a similar sector. Alternatively, the various systems 12a-12c might be oriented at different angles around a 360° axis of the tower 10 so that different sectors are defined by each RF link system 12a-12c.

The microwave backhaul antennas 14a-14c are illustrated as being directed in various different directions. In that way, the microwave backhaul signals are sent to multiple points from the single tower point to backhaul signals to those multiple points, such as multiple switching offices, or to other towers. Tower 10 and the associated RF link and microwave backhaul will generally operate within allocated frequency bands which are recognized or authorized by governmental bodies such as the Federal Communications Commission (FCC), or any similar foreign counterparts, such as the European Telecommunications Standardization Institute (ETSI) in Europe, which are intended for use for wireless and microwave communications. Similarly, the present invention is directed for operation in various conventional wireless and microwave bands used for RF links and microwave backhaul.

Figure 2 illustrates a cell tower incorporating various embodiments of the present invention. The shared tower system of the invention provides an array 20 of RF link sector antennas 24, to be shared by multiple service providers. As illustrated in the Figure, the array of sector antennas 20 is positioned on the tower top, and thus all potential service providers are given tower top access, in accordance with one aspect of the

present invention. This location, of course, increases the revenues paid by each service provider to the tower owner.

Each individual RF sector antenna 24 provides multiple and simultaneous individual signal beams in the sector for each individual service provider using the array. That is, the beams provided for each service provider are specifically tailored according to the direction and performance criteria set forth by that service provider in accordance with another invention aspect. Additionally, and in accordance with still another aspect of the present invention, digital beam steering is provided so that each service provider has flexibility with respect to their multiple beams for all sectors serviced by the tower 10a. By providing multiple, individually-steered beams for each service provider, the carrier to interference (C/I) performance criteria for the service provider is improved. The present invention offers such performance improvement for each individual service provider.

Similarly, the array 22 of microwave backhaul sector antennas 26 provides multiple, simultaneous beams in each sector in different directions which provide the desired point-to-multipoint characteristics which are necessary for the microwave backhaul signals to reach the various locations remote from the tower (e.g., switching offices, other cell towers, etc.). Digital beam steering is also provided for the microwave backhaul beams of each service provider and each sector antenna 26 to provide flexibility in the microwave backhaul operation. The present invention not only allows a greater number of providers access to a particular tower without physically overloading the tower, but as mentioned

above, it also provides every service provider the top location on the tower. This is extremely desirable for both the tower operator and service provider. Furthermore, the sharing of the array of sector antennas for both the RF links and the microwave backhaul reduces the operation costs for the operator, because such costs are spread out over a greater number of service providers. Furthermore, the present invention allows the use of lower capacity tower structures by reducing the large amount of hardware required to accommodate each of the numerous service providers using the tower.

Figure 3 illustrates a basic circuit schematic diagram of one embodiment of the tower sharing invention allowing multiple service providers to share the top location of a cellular tower. The embodiments, as illustrated herein, in accordance with the various aspects of the invention, may be utilized for the multiple sectors and sector antennas 24 associated with the RF link array 20 and/or with the multiple sectors and sector antennas 26 associated with microwave backhaul array hardware 22 (Fig. 2). To that end, in one embodiment of the invention, only the RF link hardware might incorporate the invention whereas the microwave backhaul is handled conventionally. Similarly, in another embodiment, microwave backhaul hardware may incorporate the present invention, whereas the RF link is handled conventionally. Alternatively, both the RF link and microwave backhaul might be handled in accordance with the aspects of the invention. Accordingly, the invention gives flexibility with respect to tower design and management to maximize service providers on a tower and thereby maximize revenues for the tower operator.

System 40, as shown in Figure 3, utilizes an antenna 42 having an array of elements which are operable to define multiple, individual beams for signals in one or more communication frequency bands. As noted above, the invention is directed to conventional wireless or microwave bands which are currently defined and utilized, but also will be suitable for other bands which may be formally recognized and designated in the future. The antenna 42 might resemble antenna 42a, shown in Figure 3A. Antenna 42a comprises an array of elements 44 which are arranged generally in a pattern including a plurality of M columns (designated 1-M) with N elements per column (designated 1-N). The M by N array of elements 44 may be formed by suitable techniques, such as by providing strip line elements or patch elements on a suitable substrate and ground plane, for example.

Utilizing an array of elements, a beam, or preferably a number of beams, may be formed having a desired shape and direction. Beamforming with an array antenna is a known technique. In accordance with the principles of the present invention, the beam or beams formed by antenna 42 are digitally adapted for a desired shape, elevation and azimuth, as desired by each individual service provider utilizing the shared tower system of the invention. In accordance with another aspect of the present invention, the antenna 42 is driven to adaptively and selectively steer the beams as necessary for the service provider.

In beamforming, according to the invention, individually manipulating the signals to each array element 44 allows beam steering in both azimuth and elevation. Alternatively, azimuth beam steering may be

more desirable than elevation beam steering, and therefore individual signals to columns 1-M are manipulated, that is the individual columns are manipulated to provide a beam which may be steered in azimuth while generally having a fixed elevation. The present invention utilizes the aspects of such digital beam steering for the desired results within the shared tower system.

Referring again to Figure 3, antenna 42 is shown to also include amplifier circuits 48 associated with each of the array columns 1-M. While such amplifier circuits may be located at the base of a cellular tower, as is conventional, in accordance with one embodiment of the present invention, it is desirable to utilize a distributed active antenna in which the amplifier circuits 48 are incorporated within the antenna structure 42 along with the radiating element 44 (Fig. 3A). The amplifier circuits might be distributed to each element 44 or individual columns 1-M. Exemplary embodiments of such antennas are illustrated in U.S. Patent Application Serial No. 09/538,955, filed 03/31/00 and entitled "Antenna System Architecture" and U.S. Patent Application Serial No. 09/299,850, filed 04/26/99 and entitled "Antenna Structure And Installation" which are commonly assigned with the present application and are incorporated herein by reference in their entirety. Alternatively, the antenna may be a passive antenna without amplifier circuits, as shown and discussed in Figure 5.

The embodiment illustrated in Figure 3 is simplified, and does not illustrate individual transmit and receive paths associated with each column of the antenna array, or even each radiating element 44.

However, as illustrated in Figure 4 and discussed further herein, each column 1-M, or individual element 44, will generally incorporate a frequency multiplexor circuit 90, such as a diplexer or quadplexer, which allows individual transmit (Tx) and receive (Rx) signals to be directed simultaneously to and from the antenna 42, as is known in the art. Furthermore, as is known in the art, the amplifier circuits 48 incorporated within the transmit side of the system will generally be high power amplifiers, such as multicarrier power amplifiers (MCPA), whereas the amplifiers utilized on the receive side of the system will generally be low noise amplifiers (LNA).

Coupled to the antenna 42 is frequency converter circuitry 50 which has the necessary modulation and demodulation circuitry for upconverting and downconverting the antenna signals of the elements 44. For an RF link, the antenna signals at the antenna will be within a defined RF communication frequency band, such as a PCS 1900, or a cellular 800 band. Those RF signals are associated with up-conversion (Tx) or down conversion (Rx) and one or more intermediate frequencies (IF) through the frequency converter circuitry 50. Similarly, for microwave backhaul, the antenna signals are in microwave frequency band, and are converted between that frequency band and one or more IF frequencies.

Returning to Fig. 3, the frequency converter circuit 50 will generally include a plurality of mixers 52 driven by a local oscillator (LO) signal from an LO synthesizer 54. Figure 3 basically illustrates one level or stage of frequency conversion by a single stage of mixers 52. As will be understood by a person of ordinary skill in the art, additional stages of

mixers and conversion steps may be incurred as necessary for converting the antenna signal to an IF form for further processing. Furthermore, the individual mixers 52 are actually representative of the up-conversion and down-conversion which would occur between the transmit and receive bands as illustrated individually in Figure 4. In one embodiment, the frequency conversion is handled for the entire communication frequency band, whether RF or microwave.

The signals associated with the antenna 42 are referred to herein as “antenna signals,” and they are of a form for transmitting and receiving information through the antenna 42. After or before the antenna signals are frequency converted, the signals are referred to generally as IF signals to distinguish them from the RF or microwave antenna signals. The nomenclature utilized is not to any way to limit the invention, but rather, is used to refer to the signals at different stages of their processing.

The resulting IF signals from the converted frequency band are further converted to digital IF. Digital conversion circuitry 56 converts the signals between IF signals and digital signals within what is referred to herein as a defined digital band corresponding to the entire RF or microwave communication frequency band in one aspect of the invention. The digitized IF signals are often referred to as digital IF. The digital conversion circuitry 56 converts the signals to be further digitally signal processed for interfacing with a service provider, as discussed further hereinbelow. The entire communication frequency band is converted and represented in the converted digital IF band. Illustrated in Figure 3 are circuit blocks 58 associated with each column 1-M and indicated as A/D

for Analog-to-Digital and D/A for Digital-to-Analog. The A/D sections of such blocks are generally attributed to the downlink or receive side of the circuit and designate circuitry to provide an analog-to-digital conversion, whereas the D/A portions of the blocks are generally attributed to the uplink or transmit side of the circuit, and designate circuitry to provide digital-to-analog conversion. Generally, the digital conversion circuitry converts between the entire IF band at the antenna side and a corresponding digital IF band at the processing side. Generally, the digital conversion circuitry 56 converts the signal to a form which may be readily processed by known digital signal processing (DSP) techniques, such as channel digital signal processing, including time division techniques (TDMA) and code division techniques (CDMA). The digital signals, at that point, are in a defined digital band which is associated with the antenna signals and a communication frequency band, such as a PCS 1900 band. The digital IF signals in the defined digital band are coupled with digital signal processing circuitry 70 through converters 60, 61 and fiber optic cables 62. The converters 60, 61 are digital-to-fiber converters, and allow the signals of the digital IF band, to be routed to the digital signal processing circuitry of each T providers.

In accordance with one aspect of the invention, the digital signal processing circuitry 70 for a plurality (T) of service providers, is operable to process and provide the signals associated with the service provider for the purposes of wireless communication. The digital signal processing circuitry 70, for example, will provide the desired modulation and demodulation associated with the service provider. The digital signal

processing circuitry 70 is also operable to define an individual beam, or multiple individual beams, simultaneously for each individual service provider, utilizing an antenna array 20, 22. The antenna is thereby digitally driven or executed to define and steer the beams of the service provider. Accordingly, in accordance with one aspect of the present invention, each digital signal provider has its own set of beams, which may be configured to point in various different directions generally unrelated to the beams of another service provider utilizing the same antenna array. As such, the present invention customizes the antenna array 20, 22 for each service provider. This is extremely desirable for both the service provider and the entity owning and operating the tower. A single array is used for all providers, and all providers have the tower top location.

Referring to Figure 3, in accordance with one embodiment of the invention, the digital IF band is duplicated through a digital multiplexor 72 , and the multiple duplicated digital IF bands 74 are coupled to digital signal processing circuitry 70 through filtering circuitry 76, including a plurality of bandpass filters, BPF(1) - BPF(T) where T is the number of providers associated with the antenna array. Corresponding to the number of service providers, the digital signal processing circuitry 70 will include individual signal processing circuitry for providers referred to as 77(1-T). The digital IF band is passed through the plurality of bandpass filters of the filtering circuit 76 to thereby isolate and define individual portions of the digital IF band corresponding to the antenna signals of the individual service providers. For example, 15 MHz of a PCS 1900 band might be defined for AT&T, while another 15 MHz band portion might be defined for

Sprint, and so on, for the various service providers. The individual digital signal processing circuitry 77(1-T) for each of the multiple service providers is operable to process channel information associated with that provider's signals, while digitally defining individual beams simultaneously for each individual service provider. Furthermore, the digital signal processing circuitry for each provider is operable to provide digital beam steering as necessary to selectively and desirably steer the beam in azimuth and/or elevation, as desired by the service provider.

Referring to Figure 3B, the digital signal provider circuitry 78 for a service provider X is shown and includes a channel DSP circuit 80, as well as a digital beam processor 82 for digital beam forming and digital beam steering in accordance with certain aspects of the invention. The DSP circuitry 78 for a provider, in combination with the filtering circuitry 76 defining a band portion for that provider, allows each provider a specifically tailored antenna with multiple, simultaneous, and individual beams and digital beam steering of those beams. The various beams for the different providers may be oriented in different directions and have different shapes.

Such features of the invention are certainly desirable in an RF link sector antenna wherein the beams may be selectively directed for an improved C/I ratio. Similarly, for a microwave backhaul application, the invention provides multiple simultaneous beams in different directions for point-to-multipoint operation, thereby eliminating the need for multiple microwave backhaul antenna structures pointing in various different directions around the tower. Still further, in accordance with another

aspect of the invention, the invention would be utilized for both the RF link system and/or the microwave backhaul system for a provider.

Referring again to Figure 3, within a desired distributed active antenna (DAA), the amplification circuitry 48 might be incorporated directly with the array elements in a single antenna structure, at the top of the tower. The frequency converter circuitry 50 and digital converter circuitry 56 might also be incorporated within the active antenna at the top of the tower. The signals are then passed back and forth between the tower top and the base of the tower and wherever the digital signal processing circuitry 70 is located, by fiber optic cable 62.

Figure 4 illustrates an alternative embodiment of the invention showing individual transmit and receive paths. Specifically, circuitry for such a path is shown for an individual column of N array elements, as shown in Figure 3. In Figure 4, M columns define the antenna structure, and the circuit is duplicated for each column. Such a circuit would essentially provide for azimuth beam steering in accordance with the principles of the present invention. In order to provide for elevational beam steering as well, the circuit would be reproduced for each of the M x N elements of the antenna. For the purposes of illustration, the embodiment of the invention will be disclosed with respect to a single column of elements in the antenna.

An antenna signal in a communication frequency band and associated with column 1 passes through a frequency multiplexor 90 which operates at one or more desired communication frequency bands, such as, for example, a PCS 1900 band, or a cellular 800 band. Through

the frequency multiplexor 90, the receive signal 92 and transmit signal 94 are separated or joined to be individually processed or transmitted, as is conventional. Turning to the receive signal 92, the signal passes through a suitable amplifier, such as an LNA 96, and is split by a splitter 98 to provide signals for a series of K bandpass filters 100, indicated as F_1-F_K. The bandpass filters 100 divide the frequency communication band into a number of smaller bands or band portions for frequency conversion rather than a frequency conversion of the entire frequency band as noted above. Frequency converter circuitry, designated generally as 50, includes a plurality of mixers 102 driven by an LO synthesizer 104 for downconverting portions of the band from microwave or RF frequencies to IF. Controls (not shown) might be used to control the LO synthesizer and the other frequency conversion circuitry. As discussed hereinabove, the antenna utilized might be a distributed active antenna where the array elements, frequency multiplexor, and amplifiers are incorporated into a single antenna, as indicated by bracket 42. Alternatively, the antenna may be a passive antenna wherein the multiplexing, amplification, and frequency conversion circuitry are located elsewhere, such as at the base of the tower, or removed from the antenna as discussed further hereinbelow with respect to Figure 5.

The receive signal 92, and specifically the multiple band portions 100, are digitally converted through a series of A/D converters 106 (e.g. 41 MSPS, 12-14 bit) after being downconverted in band portions from the RF or microwave frequency communication band. The resulting groups of digital IF signals 103, are multiplexed by a digital multiplexor 108 and

converted for digital transmission on fiber optic cable by a digital-to-fiber converter 60 as discussed with respect to Figure 3. As illustrated in Figure 4, a receive and transmit signal will be generated for each of the antenna columns 1-M. In the embodiment illustrated in Figure 4, the entire communication band is divided for readily being downconverted, as the communication frequency band which may be 60 MHz or wider might more easily be converted and digitized in that way rather than handling the entire band. Fiber optic cables 62 then run to appropriate filtering circuitry 76 and digital signal processing circuitry 70 as described above with respect to Figure 3. The transmit side of the embodiment illustrated in Figure 4 utilizes a suitable high power amplifier 110, such as a multicarrier power amplifier (MCPA). The upconverted band is supplied to amplifier 110 through a low power combiner 112. The frequency conversion circuitry also utilizes a plurality of bandpass filters 114 indicated as F_1-F_K. Mixers 116 are driven by the LO synthesizer 104 for the upconversion of the signal. A digital IF signal provided on fiber cable 62 from a service provider's digital signal processing circuitry is multiplexed through a digital multiplexor 108, and the digital IF signal is then converted through a series of digital to analog (D/A) converters 118 (e.g. 41 MSPS, 12-14 bit) to an IF before being upconverted to RF or microwave to be transmitted by antenna 42.

Figure 5 illustrates another alternative embodiment of the invention, similar to the general illustration in Figure 3, wherein passive antenna elements 124 are utilized at the top of the tower rather than a distributed active antenna. Coaxial cables 122, at least one for each column, are

directed down the tower in the conventional fashion, and the amplification circuitry, frequency converter circuitry 56, filtering circuitry 76, and digital signal processing circuitry 70 is at the base of the tower or beyond the base of the tower. In that way, the present invention might be retrofitted into existing cell tower structures utilizing passive antenna elements. The embodiment as described and shown in Figure 4, might also be incorporated into a passive antenna scenario similar to that illustrated in Figure 5.

While the present invention has been illustrated by the description of the embodiments thereof, and while the embodiments have been described in considerable detail, it is not the intention of the applicant to restrict or in any way limit the scope of the appended claims to such detail. Additional advantages and modifications will readily appear to those skilled in the art. Therefore, the invention in its broader aspects is not limited to the specific details representative apparatus and method, and illustrative examples shown and described. Accordingly, departures may be made from such details without departure from the spirit or scope of applicant's general inventive concept.